REPORT ON THE

2ND FEDERAL/PROVINCIAL WORKSHOP ON

GROUNDWATER DATABASES

The Halifax Citadel Inn

Halifax, Nova Scotia

November 20 and 21, 1990

91-05879/

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Workshop Chairman: J.A. Gilliland

Rapporteur: Dean Walker

Introduction

Representatives of seven of the ten provinces attended the Workshop. (Attendees are listed at the end of this report, Attachment 1) Provinces not represented were Quebec, Saskatchewan and British Columbia. In addition to the provincial representatives, various federal people with an interest in groundwater data-bases attended. The North West Territories and Yukon Territory were not represented. The provisional agenda is appended (Attachment 2), but is of academic interest only, as discussions did not follow the proposed format.

November 20 - Morning and Afternoon Sessions

The Workshop opened with an introduction by the Chairman, and began by addressing the discussion document prepared by John Gilliland and Don Farley entitled "Guidelines for Groundwater Data Systems: Federal/Provincial Workshop Nova Scotia - November 20-21, 1990", (Attachment 3).

Brief presentations were made by each province, each of which reconfirmed the general conclusions reached at the first Workshop in Saskatoon. This was particularly valuable in the case of the three provinces which had not attended the first workshop (Ontario, Nova Scotia and Prince Edward Island), as it confirmed that all provinces are facing the same problems and are attempting to tackle them in similar ways.

There was general agreement that the approach proposed in the Gilliland/Farley document was the right way to go and that work should proceed to refine and flesh it out.

Some specific items discussed were:

a) The system proposed for recording locations and time (UTM or Lat./Long. and time referred to some standard meridian, both with indicators of precision) is acceptable to all.

b) Lithological logs, well and aquifer characteristics and other time-independent data should be dealt with separately from time dependent data such as hydrographs, chemical data, pump-test data, etc., i.e. they should be stored on different files.

c) Users of the data, both present and future, include consultants, industry, the general public, municipalities, well drillers and regulatory agencies (usually the agency supporting the data-base, but also agencies from other jurisdictions).

d) As emphasised at the Saskatoon workshop, the design, content and operation of groundwater data banks must reflect real-world user's needs. These needs can be summed up in the phrase "aquifer management", which includes both groundwater resource management and groundwater contamination aspects. As individual provinces have differing needs and geographic characteristics, it is to be expected that data-banks designed to address these needs will differ.

e) However, there are certain fundamental needs which must be met by any scheme for aquifer management. Therefore there are certain requirements for data banks which are common to all agencies involved with aquifer management and, at the same time, basic to all groundwater data-banks.

   It was agreed that an aquifer inventory is one of these basic requirements. In order to be able to deal with aquifers such as inter-till sands, which are individually insignificant but collectively very important sources of groundwater for many users, it was agreed that the term "inventory of hydrogeologic environments" was preferable to the more restrictive "aquifer inventory".

f) Data contained in groundwater data-banks will be subjected to a variety of processing procedures, including mathematical modelling, GIS processing, etc. Although such procedures are essential to transform the basic data into a useful output product, there are so many possible output processing procedures that they cannot be standardized or recommended as basic requirements for groundwater data-banks in general. However, it was recognized that adoption of basic standards for groundwater data-bases will facilitate the exchange of software, processing procedures, etc., between agencies.

g) The question of charging for data in groundwater data-banks was discussed, but no specific recommendations were made concerning standard practices. At present, most agencies do not attempt to recover the costs of collecting the data or the basic costs of operating the data-bank. Many agencies felt that considerable resistance would arise

from well drillers if they were to be charged for data which they, themselves were required to provide. Such charges as are levied now tend to be "add-on" costs associated with non-standard or unusually large requests for data. Access to information legislation in the various jurisdictions is making the problem of cost recovery more difficult to come to grips with.

h) There was some discussion of the water quality aspects of the Gilliland/Farley draft, but no specific amendments or additions were suggested. In nearly all jurisdictions, groundwater quality data are stored separately from the hydrogeologic data, most often by a separate agency. The water quality data agencies were poorly represented at the workshop, (although federal water quality people were present) and this is recognized as a concern which will have to be addressed. However there seemed to be a consensus that there was no fundamental problem in relating the water quality data to the hydrogeological data even though the two types of data are held in different data-bases.

i) The cost of transferring data from its collection point in the field to the data-bank - the process of data capture - was the subject of considerable discussion. There is no question that this is a major bottleneck in maintaining up-to-date groundwater data-bases and that several agencies have had considerable difficulties in this respect. It was agreed that it would be worthwhile to conduct one or more pilot projects to investigate the possibility of automating this procedure, (e.g. by the use of computerized remote access terminals). Alberta, New Brunswick, Manitoba and the federal government expressed an interest in participating in a joint project to explore this and other possibilities further.

November 21 - Morning Session

Discussion, Wrap-up and Recommendations

On the second day, there was general agreement by the group that the major components of the data-base are:

1. Site Location Information (in space and time, common to all data files)
2. Well Construction Information (time independent)
3. Lithological Logs (time independent)
4. Aquifer Characteristics (split into time dependent and fixed parameters)
5. Chemical Analysis Data (time dependent)

It was agreed that the next step should be to flesh out the Gilliland/Farley draft with detailed specifications of the basic parameters required in all groundwater data-bases designed for aquifer management, based on the considerations discussed at the Workshop.

J.A. GILLILAND AND D. FARLEY UNDERTOOK TO DO THIS, in consultation with the provinces and with the federal people involved in developing groundwater data-bases.

In the interests of cutting down travel expenses, it was agreed that a number of regional workshops should be held, in about 3 to 4 months time where regional people would discuss and comment on THE NEXT DRAFT DOCUMENT TO BE PREPARED BY GILLILAND AND FARLEY, in consultation with provinces and federal people. ROGER HARDICK (ALBERTA) OFFERED TO HOST A WESTERN REGIONAL WORKSHOP in Edmonton, JIM ANDERSON (NEW BRUNSWICK) VOLUNTEERED TO HOST THE ATLANTIC REGION WORKSHOP. Venues for other workshops will be arranged to the convenience of the participants. GILLILAND AND FARLEY UNDERTOOK TO COLLATE INPUT FROM THESE REGIONAL WORKSHOPS AND PREPARE A FINAL DRAFT DOCUMENT which would be discussed (and, it is to be hoped, approved and adopted) at the next full meeting of the whole group.

DON FARLEY ALSO AGREED THAT HE AND KEN STEWART WOULD WORK TOGETHER WITH OTHERS INTERESTED ON DEVELOPING A PILOT STUDY FOR AUTOMATING THE DATA CAPTURE PROCESS.

HUGH LIEBSCHER (ENVIRONMENT CANADA, PACIFIC AND YUKON REGION) OFFERED TO HOST THE NEXT FULL MEETING IN VANCOUVER AND IT WAS AGREED THAT IT SHOULD TAKE PLACE JUNE 11 AND 12, 1991.

PARTICIPANTS ALSO AGREED TO SEND A LIST OF ANY GROUNDWATER RELATED PROGRAMS OR SOFTWARE THEY ARE CURRENTLY USING, WITH THE NAME OF A CONTACT PERSON WHO CAN PROVIDE FURTHER INFORMATION TO J.A. GILLILAND WHO WILL COMPILE A LIST TO BE DISTRIBUTED AT THE NEXT FULL MEETING.

The Workshop ended at 12:00 noon, November 21, 1990.

The Working Group's thanks and appreciation are extended to Terry Hennigar (Environment Canada, Atlantic Region), who sponsored this meeting and to Dean Walker (also EC/AR), who was in charge of local arrangements and acted as rapporteur.

ATTACHMENT 1

List of Attendees

2ND FEDERAL/PROVICIAL WORKSHOP ON GROUNDWATER DATABASES

November 20 -21, 1990

The Citadel Inn Halifax

Participant	Representing	PHONE Number	FAX Number
1. Dean Walker	IW/Env. Canada	(902) 426-3266	(902) 426-4457
2. Jim W. Robinson	Nfld.Env. & Lands	(709) 576-2539	(709) 576-1930
3. Herb Doane	N.S. Environment	(902) 424-5300	(902) 424-0503
4. John Power	WRB, Env. Cda.	(819) 953-3677	(819) 997-8701
5. Peter Brooksbanks	WQB, Env. Cda.	(819) 997-3424	(819) 997-8701
6. George Somers	P.E.I. Environment	(902) 368-5046	(902) 368-5830
7. Alan Robison	P.E.I. Environment	(902) 368-5048	(902) 368-5830
8. Frank Cruickshanks	IW/Env. Canada	(902) 426-6885	(902) 426-4457
9. Hugh Liebscher	Env. Cda, Vancouver	(604) 666-0807	(604) 666-3325
10. Jim E. Anderson	N.B. Environment	(506) 457-4848	(506) 453-2265
11. Roger Hardick	Alberta Environment	(403) 427-6231	(403) 422-2876
12. Lock Gray	Manitoba Natural Res.	(204) 945-7403	(204) 945-7419
13. Edward Nicolson	Env. Canada/IWD	(819) 997-2324	(819) 997-8701
14. Ken Stewart	WP&M, IWD	(819) 997-1236	(819) 997-8701
15. Don Farley	WP&M, IWD	(819) 953-1528	(819) 997-8701
16. Sam Singer	MOE, WRB	(416) 323-4882	(416) 965-9807
17. Terry Hennigar	WP&M, IW, Atlantic	(902) 426-3266	(902) 426-4457
18. John Gilliland	Env. Canada, Ottawa	(819) 953-1521	(819) 997-8701
19. Duane McNaughton	Env. Canada SPB/ICS/WNR	(403) 468-8029	(403) 495-2615
20. Geoff Howell	IW, Env. Canada	(902) 426-4196	(902) 426-4457

ATTACHMENT 2

PROVISIONAL AGENDA

SECOND FEDERAL/PROVINCIAL WORKSHOP ON GROUNDWATER DATA BANKS

DAY 1: Morning Session

09:00 - 09:30 A.M.	Welcome, Introductory Remarks	J.A. Gilliland
09:30 - 11:30 A.M.	Requirements for Aquifer Management	Plenary Session
	Inventories of Aquifers Aquifer Characterization Aquifer Management - Planning - Operations - Development of Systems System Users	
10:15 - 10:45 A.M.	Coffee	
11:30 - 12:00 P.M.	Selection of Working Groups	
12:00 - 13:00 P.M.	Lunch	

PROVISIONAL AGENDA

SECOND FEDERAL/PROVINCIAL WORKSHOP ON GROUNDWATER DATA BANKS

DAY 1: Afternoon Session

13:00 - 14:30 P.M.	Data Bases for Aquifer Management	Working Groups

1) **Data Capture**

- From field measurements to data banks
- Problems, e.g., manpower constraints
- Possible solutions/opportunities field logging equipement data base management techniques

14:30 - 15:00 P.M.	Discussion - Coffee	Plenary Session
15:00 - 16:30 P.M.	Data Bases for Aquifer Management	Working Groups

2) **Data Base Definition**

- Components, e.g., lithology logs, well construction, hydrographs, drilling equipement, etc.
- Minimum requirements for data, e.g., precision, locational systems, reliability codes, etc.
- Compatibility considerations, e.g., common terminologies/codes for lithological logs, interconvertible systems for locations
- Minimum requirements for hardware, e.g., desk-top PC with hard disk
- Minimum requirements for software, e.g., commercially available Data Base Management Systems (DBMSs)

16:30 - 17:00 P.M. Discussion

PROVISIONAL AGENDA

SECOND FEDERAL/PROVINCIAL WORKSHOP ON GROUNDWATER DATA BANKS

DAY 2: Morning Session

09:00 - 10:15 A.M.	Data Bases for Aquifer Management	Working Groups

3) **Outputs**

- Management models/outputs (very simple to very sophisticated)
- 3-D display capability (e.g., for displaying contaminant plumes)
- Anticipated queries (e.g., from well drillers, regulatory agencies, etc.)
- GIS technologies
- Publications, e.g., annual lists of wells drilled, etc.

10:15 - 10:45 A.M. Discussion - Coffee

10:45 - 12:00 P.M. Data Bases for Aquifer Management

4) **Confidentiality/Security Considerations**

- Sensitive data - ways to deal with them
- Security concerns - protection of integrity of data, backup, physical/electronic security, etc.

5) **Telecommunictions Aspects**

- User access - to include access by drillers, "public", other government agencies, etc.

6) **Other Considerations**

- Software portability, e.g., to what extent should Manitoba's system be capable of running on New Brunswick's hardware? Is this desireable?
- Bilingual system capability. How is this question best handled?

12:00 - 13:00 P.M. Lunch

PROVISIONAL AGENDA

SECOND FEDERAL/PROVINCIAL WORKSHOP ON GROUNDWATER DATA BANKS

DAY 2: Afternoon Session

13:00 - 16:30 P.M.	General discussion, selection of Working Groups, next meeting, other business, wrap-up	Plenary Session

ATTACHMENT 3

PROPOSED GUIDELINES FOR GROUNDWATER DATA SYSTEMS FOR DISCUSSION AT FEDERAL-PROVINCIAL WORKSHOP NOVEMBER 20-21, 1990

Hydrogeological Aspects
by J.A. Gilliland

Type of System

The minimum system to be considered should be based on a desk-top, PC-type computer with hard-disk storage of at least 40 megabytes.

Rationale: Paper-file based, microfiche and other non-computer oriented systems are very difficult to design to accommodate uses other than those of the primary organization and tend to be man-power intensive. Such files can (and probably should) be maintained for backup and archival storage purposes but should not be used for day-to-day operational purposes. The availability, cost and convenience of the desk-top PC is now so good that such a capability should be readily available to any government agency with essentially insignificant cost implications.

Traditional main-frame based systems running on a batch or general purpose remote terminal are both more inconvenient and more inefficient in terms of providing on line turnaround as compared with PCs. High powered main-frames such as super-computers will probably see increasing use for groundwater work but more in the area of data manipulation, modelling etc., rather than as primary data storage and retrieval facilities. Today, it is a relatively trivial problem to interface such super-computers to PC-based work-stations so that storage of the data at the main-frame site is not a necessary or even a desirable feature of data storage systems for groundwater data.

Purpose of Systems

Groundwater data storage systems should be designed and operated to serve the needs of agencies' groundwater management plans. These plans should provide for:

1) the management of aquifers used (or potentially usable) for water supplies; and

2) the management of groundwater contamination (site specific or non-point-source) where such contamination may pose a threat to:

   a) groundwater supplies;
   b) lakes, rivers or any other water body used for water-supply purposes; and
   c) any water or other resource with economic, social or environmental value to society.

Fundamental Locational Parameters

All groundwater data, to be useful, must relate to a specific point in space and a specific instant in time. Therefore, a fundamental requirement of all groundwater data systems is the capability to store data relative to a point defined in space/time. Such points are defined, relative to the earth's surface by:

a) latitude and longitude;
b) elevation above a standard reference point (e.g. mean sea level); and
c) date and time of observation relative to a standard meridian (e.g. Greenwich).

All systems should therefore include these parameters (or equivalents) as fundamental reference parameters for each data point.

The use of latitude and longitude for horizontal locations can be cumbersome and inconvenient and equivalent systems which can be readily converted to latitude and longitude are often preferable. One such system in wide use is the Universal Transverse Mercator (UTM) system, for which automatic conversion routines are readily available.

The use of legal land descriptors (such as the Section/Township/Range system prevalent in Western Canada) must not be used for the purposes of establishing geographic locations. Such systems are often invaluable for the purposes of particular groundwater agencies and, where they exist, may be essential to the day to day work of the agency concerned, but they are not a substitute for proper geographic locational coordinates. Computer codes exist to convert Section/Township/Range "locations" to UTM or lat/long values, but:

a) they are not widely available;
b) they are not universally applicable to all areas, even in the West (e.g. in cities and towns; in the northern, unorganized areas of the Prairie provinces; along some rivers where the river lot system of subdivision has been used); and
c) they are not always accurate (in areas where errors occurred in the original land surveys).

Precision/Accuracy of Locational Parameters

Groundwater data are used for many different purposes. For example:

A lithological log may be used by a well driller to locate the best spot for drilling a water supply well, or by a hydrogeologist cleaning up a waste site or by an engineer in charge of a grouting project and so on.

A groundwater hydrograph may be used to assess the reliability of a municipal water supply, or to determine the hydrogeologic characteristics of an aquifer or to monitor the possible impacts of climatic change or to forecast or record the effects of earthquakes.

Chemical analyses of groundwater may be used to determine the suitability of well water for irrigation or to assess the effects of acid rain on the hydrologic regime or to detect the existence and monitor the development of a contaminant plume from an industrial waste site.

These various applications require different precisions and accuracies in the fundamental locational parameters used to locate the measuring point in space or time.

A well driller attempting to construct a well for a client requires knowledge of the areal location of a permeable horizon to within perhaps a few tens or hundreds of meters and can use information located to a precision/accuracy of up to a kilometer or more in some situations. In terms of elevation, the requirements are somewhat more stringent - the cost of a 100-meter well is significantly greater than that of a well of only 10 meters and the cost of a kilometer-deep well would be prohibitive. Therefore, the precision/accuracy of the vertical coordinate should be greater than for the horizontal location, perhaps of the order of 1 to 10 meters. The precision/accuracy of the time dimension i.e. when the lithological log was made, is essentially immaterial to the well driller. Generally it does not much matter to the driller whether the log was made yesterday or 20 years ago. The time precision required here would be at best a year and more likely more than this.

For a contamination problem and the grouting problem, the precision/accuracy requirements are much more restrictive. A contamination investigation will generally require a horizontal accuracy of at least 1 meter and sometimes less. Vertically, an accuracy of 1 cm or even less in some critical situations is needed. A grouting engineer would also need about the same order of accuracy. In addition, if fracture permeability is a significant consideration, very accurate measurements of fracture aperture may be required - to better than a millimeter in many cases. These requirements are reaching the limits of what can be expected from a standard, visual lithologic log and the smaller aperture openings must be measured in the laboratory. Nevertheless, it would normally be expected that fractures as big as 1 cm would be recorded on a lithologic log. The time dimension also calls for much better accuracy than for the well drillers situation. If the contamination situation could have generated lithologic changes such as changes in colour or in fracture development in clays, then the time at which the log was made is obviously of importance. Similarly, a grouting engineer wants to know whether the log was made before or after the injection of cement. The time accuracy required in these two cases is therefore of the order of a day to a week.

Applying similar kinds of reasoning to the other examples, the range of accuracies required for the various kinds of hydrogeological data lie roughly in the following ranges:

TABLE

PRECISION/ACCURACY REQUIREMENTS FOR LOCATION

Type of Data	Horizontal	Vertical	Time
Lithologic Log	1 meter to several hundred meters	1 cm to 5 meters	1 day to several years
Hydrographs	1 meter to several hundred meters	1 mm to ½ meter	15 secs to 3 months
Chemical Analyses	As for lithological log		1 day to 1 year
Well Construction Data	As for lithological log		
Geophysical Logs	As for lithological log		1 day to 1 year

NOTE: The 15 second time precision for hydrographs is required to resolve long-period earthquake waves.

Therefore, any groundwater data storage system capable of responding to the variety of demands likely to be placed on it today should have the capability of recording the primary location parameters to the precision indicated below:

	Precision/Accuracy
Horizontal Coordinates (Lat/Long; UTM)	1 meter
Vertical Coordinate (Elevation)	1 cm
Time (relative to GMT)	15 secs

A distinction should be made between the precision of a measurement and its accuracy. For example, at a particular site, it is much more important that horizontal locational information be known accurately relative to a nearby local datum than it is to be sure that the position of the site is accurately located on the earth's surface. In other words, it is important to know, say, the position of an observation well relative to a pumping well to an accuracy no worse than a meter, whereas the geographic coordinates of the two wells on the earth's surface may be in error by a matter of miles without causing any significant practical problems. The important thing is for the data storage system to be able to record the data to sufficient precision (i.e. ±1/2 meter).

Because of the importance of the precision of locational data, some qualifier should be appended to each set of recorded data to indicate its degree of precision. The form and format of this qualifier should

therefore be standardized across all compatible systems, in addition to the form of the locational data itself.

Lithological Logs

The lithological log is probably the most important and widely used component of any groundwater data storage system. These data describing the geological formations encountered in a bore-hole are essential to the correct interpretation and use of all the other kinds of data which might be contained in a groundwater data storage system.

The quality of lithologic logs varies enormously, depending on who and what kind of organization sponsored the drilling (which determines which depths and kinds of formation are of interest) and on the professional/ technical capability of the person who actually performed the logging.

If such logs are to be used by organizations other than the one maintaining the system, there will need to be provision for:

a) common (or at least convertible) codes for describing lithologies (so that one person's "sand" is the same as everyone else's); and

b) an indicator of reliability or quality. Such indicators would be useful not only to the individual hydrogeologist or well driller consulting the file, but also could be used to weight data and information points when used in machine-processed routines such as contouring packages.

Development of a standard set of codes for lithologies is not difficult (it has been done before), but it will be necessary to establish what degree of sophistication and complexity is required by external users before developing any such coding system.

Groundwater Hydrographs

These records are similar to any other time series data in that they comprise a set of two numbers, one describing the water level (or hydraulic head) and the other recording the time at which the level measurement was made. The time reading may be explicitly recorded, or implicit in the data format (e.g. for digital recorders). A wide variety of hydrograph data collected for various purposes exists - both frequency of measurement and precision of water level reading vary considerably.

A peculiarity of groundwater hydrograph data is the potential for realising very significant savings in storage costs through data compression and compaction techniques. This is because, for an annual hydrograph, most of the changes in level that occur happen during the spring thaw and run-off period. For the rest of the year most observation well hydrographs change only very slowly. Reductions in data volume of up to 3 to 4 times are possible.

If such data compaction techniques are to be used, and the data exchanged with other organizations, some common exchange format for hydrographs will have to be agreed upon, e.g. should the data be exchanged in compacted form or reconstituted? What minimum levels of precision will be acceptable, and so on.

Well Construction Data

Much the same considerations apply here as for the lithological logs. If such data are to be exchanged, provision will have to made for establishing mutually compatible coding systems, defining what data are and what are not to be included and so on.

Geophysical Logs

In the groundwater business, the routine running of geophysical logs in boreholes is still very much the exception rather than the rule. The most commonly run logs are SP/Resistivity logs, but a wide variety of techniques have been used, up to and including down-hole TV cameras.

Apart from the SP/Resistivity type of log, the purposes of many of the other kinds of logs are often highly specialized and sufficient data may not exist to warrant thinking about data exchange between agencies. If, nevertheless, such data are to be exchanged, agreement will be needed on standards e.g. kinds of log to be included, methods of storage and formats for exchange etc.

Chemical Analytical Data

To a considerable extent, the storage of groundwater chemistry parameters - whether traditional or toxic chemical - has been the province of the chemical analytical specialist organizations i.e. those which actually carry out the chemical analyses. Generally, these analytical results are stored in general-purpose water quality systems such as NAQUADAT along with water quality analyses from other sources such as surface water.

There is nothing wrong with this approach - after all most people now recognize that the dream of a single "super-system" containing all the kinds of data pertaining to water is just that - a dream. There is no particular difficulty in cross-referencing systems so that the water chemistry data relating to a particular well or piezometer can be readily accessed and vice-versa.

However, the fact is that most water quality data banks reflect the priorities and concerns of analytical chemists, not those of hydrogeologists. Accordingly, much attention is given, (quite rightly) to issues such as how to deal with changes in analytical methodology, QA/QC and so on. Whereas hydrogeologists are not unconcerned with these kinds of question - after all they are just as interested as the chemists in knowing that the numbers mean what they say - but hydrogeologists have other, equally important concerns which are poorly considered, if at all, in the design and operation of water quality data banks.

For example, one concern which is assuming increasing importance for the hydrogeologist investigating contamination problems is the cost of analyses. At $1000-$2000 per parameter for some of the more exotic toxics, the numbers of such analyses that can be performed within tight budgetary constraints is strictly limited. It is quite simply not economically feasible to define and trace a contaminant plume on the basis of analyses of the (usually organic) contaminant of concern.

Accordingly, hydrogeologists are increasingly turning to the use of screening methods and proxy data to minimize the numbers of samples which must be submitted for high cost, high tech analytical treatment. Thus, a plume can be traced by simple analyses of some chemical species which would be expected to follow the same path as the contaminant of concern, e.g. simple field tests of Cl or other inorganic species often are quite adequate to define the bounds of a plume emanating from a landfill.

The use of field test kits - such as the Hach Kit - speeds up investigations considerably - at considerably reduced expense compared to using a conventional laboratory. Tests such as Microtox, while admittedly having their shortcomings as indicators of overall toxicity, nevertheless perform an invaluable function when used as screening tools to eliminate the need to analyse a lot of samples, most of which will turn out to be blank. The number of samples requiring the full high tech treatment can be reduced by up to 80 per cent (i.e. to 20 per cent of what would have been required previously). This is a very significant reduction which can make the difference between the success and failure of a particular investigation.

Yet existing water quality data banks are not set up to store the results of such "low-tech" techniques. There appears to be considerable reluctance to incorporate such relatively unsophisticated and "unreliable" data into existing data banks. To be sure there are good reasons for this reluctance e.g. if such data were incorporated, the size and cost of running existing data banks would increase substantially; there would be problems dealing with high precision, high quality data and low tech, "order of magnitude" type data simultaneously.

Nevertheless, some provision will have to be made for storing and retrieving such low tech data. Many hydrogeological investigations could not proceed without them. It would probably be preferable for the chemists to develop these systems and incorporate them into their present systems; in this way all chemical data would be stored together. However, if the chemists do not do it, then the hydrogeologists will have to do it themselves. This issue requires and deserves a lot of discussion and cooperation between chemistry specialists and hydrogeologists.

The question of chemical data compatibility and exchange adds yet another dimension to an already very complex problem.

Aquifer Inventories

Recognizing that an inventory of aquifers in a province/region is a fundamental requirement for any groundwater management plan and the basis

on which all groundwater data management systems must be designed and operated, it is essential to define the minimum requirements for such inventories.

Conceptually, at least, the minimum requirement for an aquifer inventory is fairly straightforward to define; such an inventory should include all aquifers which:

a) provide, or have the potential to provide significant water supplies; and/or
b) are, or are in danger of becoming contaminated; and/or
c) are, or have the potential to be sources of or pathways for the movement of contamination towards significant surface water bodies; and/or
d) are of particular importance for some other reason, e.g. special ecological significance.

In practice, it is necessary to translate these general principles into guidelines which can be applied objectively, although subjective judgment cannot be eliminated entirely.

Also, for the purposes of this federal/provincial workshop, the objective is to define the minimum requirements, i.e. those requirements which everyone agrees are essential in nearly every situation across the country. This recognizes the fact that there will be special considerations applying to particular provinces or regions which may dictate a much more comprehensive approach to aquifer inventories.

Some possible factors which could be applied to the definition of minimum requirements for aquifer inventories include:-

a) **Physical Size of the Aquifer**

This might be based either on the areal extent, i.e. hectares or square kilometres, or on volume, i.e. cubic metres or kilometres of the aquifer itself. A variant on this would be to use the quantity of water in the aquifer rather than the aquifer volume, but this would probably involve much more complex procedures which are probably not economically justifiable.

At our present state of knowledge of aquifers in Canada, the most useful and efficient measure is probably areal extent.

One drawback to using this parameter is the fact that much of the groundwater used in Canada is drawn from small aquifers by individual, generally rural users, and used for domestic or small farm uses (Hess report). Such aquifers, although individually not very important, add up to a very significant resource in certain areas of the country, and to leave these aquifers out of an aquifer inventory would be a major omission. Some way will need to be found to ensure that these, as well as other small but essential aquifers are not excluded from provincial/regional inventories.

b) **Aquifer Characteristics**

These would include measurements of hydraulic conductivity, or other measures of the aquifer's permeability characteristics, measures of storage capacity, maximum pumping rates etc. Specifications of what would be considered minimum requirements for testing techniques (e.g. pumping tests, slug tests, permeameter tests) would be needed, as well as some criterion for assessing the adequacy of coverage of such measurements (e.g. n permeability tests per square kilometre).

In addition some minimum criteria for groundwater chemical properties would be required, (e.g. parameters to be included - such as major ions, contaminants; areal coverage - number of sampling points per square kilometer).

c) **Observation Wells and Hydrographs**

Questions to be considered include:

i) minimum number, if any, of observation wells, both absolute number and number per square kilometre;
ii) frequency of observation;
iii) standards for design, construction, instrumentation, if any; and
iv) any other relevant factors.

Some considerations which should be kept in mind are:

1) To an extent, the degree of coverage for groundwater observation wells in an aquifer is self-regulating in that, as development of an aquifer proceeds, the amount of instrumentation installed should automatically increase to meet management needs. In an undeveloped aquifer, not much more information is required other than the fact that it is there. The first user - say a municipality - will, or should, install one or more observation wells to ensure that groundwater levels are behaving as predicted, so that when the next user comes along, there already exists some water level information. He, in turn will (should) install observation wells for his own purposes so that as the aquifer develops and more information is required to make the necessary management decisions on licencing, allocations, etc., much of that information already exists (or should exist).

2) It must be recognized that although it is in the user's own best interest for him to keep good records of water levels, he may not always do so, perhaps for short-term and short-sighted economic reasons, so that groundwater management agencies will have to give some consideration to the need for regulations, legislation etc. to ensure that the appropriate data are collected and the appropriate records kept. However, this would not appear to present any major problems, e.g. it should be easy enough to attach a monitoring requirement to the terms of a licence.

d) **Presence of Contamination or Contamination Hazards**

To be useful, any aquifer inventory will have to contain some indication of present or potential contamination situations. The aquifer inventory could contain detailed information on any actual occurrences of such contamination. However it may be preferable to deal with the detailed contamination data separately and, in the aquifer inventory, to merely note its presence with a cross-reference to the appropriate file(s).

The susceptibility of aquifers to potential contamination incidents is another area which requires discussion. Clearly it is very important to know whether or not an aquifer is vulnerable to some particular kind of contamination, so that appropriate precautions can be taken to minimize the risks of the contamination actually happening. However, whether the aquifer inventory is the place where the detailed data should be kept requires further consideration.

Systems/Database Management Aspects
by D.W. Farley

Basic Concepts

The organizations which have a mandate to collect the data, whether it be recorded head, lithological logs, permeability, aquifer delineation, chemical analysis of samples, monitoring of contamination plumes, etc., will normally be responsible for the design, maintenance and updating of their databases. Often, the ready availability of these data to other organizations can result in better management and protection of groundwater resources.

The databases will be distributed in one or more wide area networks (WAN) among the participating organizations. User groups will be identified for each database in the WAN(s) with the database administrator of the host organization issuing user IDs and passwords to authorized personnel. Costs associated with user access, such as Datapac charges, will normally be borne by the users accessing the databases. Wherever feasible, the systems will be designed to avoid the need for direct contact between the database administrator and the authorized persons within a user group when those persons wish to access a particular database.

Referencing of Databases

There are many organizations involved in data acquisition and the maintenance of databases pertaining to groundwater resources. It is often difficult knowing who is collecting what data, whether the data are readily available and what is the best route for gaining access to the data. All organized and supportable databases should be referenced in a central location. The reference should describe the data, identify the host organization, give the name, address and phone number of the database administrator, and any particulars on how the data can be accessed.

Environment Canada through the WATDOC Section will be mounting such a reference database this winter on the CAN/OLE system at the Canada Institute for Scientific and Technical Information (CISTI) of the National Research Council. The database is called DREF and will complement AQUAREF, the national water resources bibliographic reference database currently on line at CISTI. AQUAREF and DREF are available through Datapac services upon obtaining an account from CISTI. One private sector firm is currently publishing AQUAREF on CD-ROM, and another one has just recently requested the AQUAREF file for the purpose of publishing on CD-ROM. DREF will be provided to these companies at the 6-month update intervals.

Environment Canada is willing to incorporate the referencing of groundwater databases in DREF with no expected significant increase in operating or person year costs. The participating organizations would simply fill out a single form (copy attached) and provide updates. As with AQUAREF, the use of management codes permits the automated publishing of inventories of the referenced databases by subject/organization/region. Of course, the

management codes have to be judiciously selected in advance to permit obtaining the desired output.

Data Capture

In several instances data are being recorded on forms but never get converted to a computer compatible format for storing in a database. Drillers' logs in some provinces are an example. In other cases, data entry and verification are labour intensive and, consequently costly for some organizations with higher priorities.

Digital recording equipment and appropriate procedures should be selected to directly capture data in a computer compatible format for those cases that would result in a more cost-effective compilation of the database. There may be a need to customize recording equipment for some applications. A joint funding approach for developing digital recorders for identified applications would appear to be beneficial.

Backlogs of coding of recorded data should be priorized and decisions taken whether the cost of conversion would be justified by computer access to the files. Large backlogs could probably be best accommodated under a contract arrangement. Scanning procedures would probably offer the most appropriate solution for any data in a typed format.

Database Management Systems

Relational database management systems (RDBMS) are the most appropriate database management systems for handling the diverse nature of the data associated with groundwater resources. To permit an open system, the SQL (Structured Query Language) standard is proposed for any commercial RDBMS acquired under a joint arrangement.

Common strategies should be developed for dealing with the diverse nature of the data. For example, head may be recorded in a particular region to different accuracies on the time scale varying from 15 seconds to a month. If someone is looking for earthquake disturbance data, they should be able to select only those data for which the time precision is adequate for this type of analysis.

On-line databases (direct random access on disc) offer the most convenient and rapid approach for users to access groundwater related data. Disc storage costs have been decreasing similarly to the cost of processing; however, magnetic tapes are still a much cheaper storage medium for large volumes of archived data. There may be some cases where the magnetic tape medium is the most appropriate method for handling large volumes of data for which rapid access is not required. C-List procedures should be employed in such cases to permit a non-computer scientist to easily access the data. Optical discs offer another solution for handling massive volumes of data. One optical disc can hold 700 megabytes of data or 700 times the amount on a high density magnetic floppy disc.

Telecommunications

The WANs providing access to the databases by members of identified user groups should be linked to the Datapac 3000 service permitting up to 9600 baud service. At least one province has a network providing up to a T1 service between its headquarters and regional offices. CA*Net at 56 kbs was implemented on October 26, (NRC contact to U. of Toronto) and may be a financially feasible means, especially for research institutions which are already members of the network, to access distributed databases. Membership in CA*Net would also permit free telecommunications access at 56 kbs to the supercomputer facility at Dorval, Quebec, for large scale modelling applications.

Databases on the network should have a capability to handle at least 3 simultaneous users.

Geographic Information Systems GISs

A geographic information system (GIS) is a system designed to capture, store, manipulate, retrieve, display and locate data that are referenced to geographic locations. It is a depiction system usually written in a third generation language (e.g. FORTRAN, C, PASCAL. ADA), with a graphics user interface for small subsets of the database. A relational database management system (RDBMS), on the other hand, is an organized storage system for the entire database and utilizes fourth generation languages such as SQL (Structured Query language) which is the standard recommended in this document for joint federal/provincial cooperation in groundwater databases. GISs and RDBMSs complement each other, but do not replace each other.

Joint federal/provincial projects should adopt a standard interface design between the GIS products and the RDBMS. In groundwater management there is a need to encompass three dimensional space (x,y,z coordinates) along with temporal relationships. There are several interface designs commercially available or under development which could be evaluated for application to groundwater management. The Bedford Institute has adopted a particular spatial-temporal data structure referred to as the Hyspat code (Hyperspatial code) and is based on the quadtree/octree concept. Compared to CADD (Computer Assisted Drafting and Design), GIS represents a much more comprehensive software because of its database management and analytical capabilities featuring rapid interactive data analysis and production of cartographic outputs.

D-REF GUIDELINES

LANGUAGE OF DOCUMENTATION: In the last box on the top of the input form, indicate the language(s) in which documentation for the data collection or data handling system is written.

NAME OF DATA COLLECTION: Indicate the full name or title of the data collection or data handling system being described. Also provide its acronym if applicable.

PURPOSE OR OBJECTIVE: Give the reason for collecting the data or for developing the data handling system.

SPECIFIC DATA OR PARAMETERS MEASURED: Indicate what kind of data have been collected or what variables have been measured.

PERIOD OF RECORD: Provide the time span covered by the data in the collection. If the data were collected during a certain period of time, provide a start and a finish date (e.g. 15 Sept 1981-31 Aug 1988). If the data collection is ongoing, give the starting date followed by a hyphen (e.g. 1956-).

FREQUENCY OF SAMPLING: Indicate how often samples are collected (e.g. daily, weekly, monthly).

FREQUENCY OF UPDATE: Indicate how often data in the collection are revised or brought up to date (e.g. annually, seasonally).

PLACE OR REGION: Provide the full name(s) of any place(s) or region(s) at which data were collected. Include the name of any relevant countries (except Canada), provinces, territories, districts, cities, basins, rivers, lakes, etc.

LATITUDE/LONGITUDE: Indicate the latitude and the longitude (in degrees and minutes) of any cities, towns, lakes, estuaries, straits, rivers, etc., cited in PLACE. It is not necessary to code political jurisdictions (i.e. countries, provinces) or divisions of the earth's surface (i.e. continents, oceans, river basins, etc.).
The form used is: points N°' W°';
ranges N°' N°' W°' W°'

Example:			
	PL/1	Saskatchewan	not necessary
	PL/2	Moose Jaw	LL/1 N5024 W10532
	PL/3	Moose Jaw River	LL/2 N4945 N5024 W10410 W10532

COMPUTER BASED SYSTEM: If the data collection or data handling system being described is computer based, check the appropriate boxes on the left-hand side of the Input Form.

NON-COMPUTER BASED SYSTEM: If the data collection or data handling system being described is not computer based, check the appropriate boxes on the right-hand side of the Input Form.

FEES FOR DISSEMINATION: Indicate whether users must pay for access to the data or system and, if so, specify the conditions of use (i.e. the fee schedule, etc.).

AGENCY REFERENCE NUMBER: Record any internal identification number used by the collecting or storing agency to identify the data or system.

DESIGNATED CONTACTS: Indicate the name, title, affiliation, address and telephone number of the first (and an alternative) person or organization responsible for responding to queries related to this data collection or data handling system.

FUNDING AGENCY: Record the full name of the organization who paid to have the data collected or the system developed.

PUBLICATIONS: Provide full bibliographic information for any publications derived from the data in the collection.
Use the format: AUTHOR: Title of publication. Place: Publisher, Date. (series name no.).

REFERENCES: Provide full bibliographic information for any publications consulted in collecting, or useful in analysing the data. Publications that explain the functioning of the data handling system should also be cited under **REFERENCES**. The format should be the same as that used for **PUBLICATIONS**.

KEYWORDS: Provide any terms that accurately describe the subject coverage of the data collection, the techniques used in collecting the data, the method of processing the data, etc. Keywords are descriptive, not quantitative, therefore, do not repeat terms used in **PARAMETERS MEASURED**.

CLASSIFICATION: Choose and rank up to three general headings that best reflect the subject coverage of the data. For example, if a data collection deals with the quality of groundwater sources in a region, mark the form:

(01) ___ Physiographic data/Données physiographiques
(02) ___ Streamflow and water level/Débit et niveau de l'eau
(03) 2 Groundwater/Eaux souterraines
(04) ___ Glaciology/Glaciologie
(05) 1 Water quality/Qualité de l'eau (major focus)
(06) ___ Sediment/Sédiment
(07) ___ Water use/Utilisation de l'eau
(08) ___ Planning and management/Planification et gestion
(09) ___ Other/Autre:

DESCRIPTION: Provide a free-text description of the data collection or data handling system. This description need not repeat material contained in the other fields, but should include details like the source of the data, the acquisition method, the sample size, and the method of organizing the data.

D-REF

DRN	UPD	RSC	LANG

Name of data collection/Nom de la collection de données (NAME)

Purpose or objective/But ou objectif (OBJ)

Specific data or parameters measured/Données spécifiques ou paramètres mesurés (PAR)

Period of record/Date de la cueillette (PER)

Frequency of sampling/Fréquence d'échantillonnage (FOS)

Frequency of update/Fréquence des mises à jour (FOU)

Place or region where data collected/Endroit où les données ont été recueillies (PL)

Latitude/Longitude (degrees and minutes/degrés et minutes) (LL)

Computer based systems/Systèmes informatisés (CB)

Type of computer base/Genre de système informatisé (TCB):
- ☐ mainframe-mini application/mini ordinateur ou ordinateur principal
- ☐ micro/micro

Storage media/Moyen utilisé pour la mise en mémoire (SM):
- ☐ magnetic tape/bande magnétique
- ☐ disk/disque
- ☐ diskette/disquette
- ☐ other/autre
- . briefly describe/brève description:

Database management system/Système de gestion de bases de données (DMS):
- ☐ commercial/commercial
- ☐ customized/selon spécifications de l'utilisateur
- . briefly describe/brève description:

Location of database or datafiles/Emplacement de la base de données ou des fichiers de données (LOC):

Dissemination of data/Diffusion des données (CDD):
- ☐ Data access/accès aux données
  - ☐ terminal access/accès par terminal
    - ☐ non public access/accès limité
    - ☐ public access/accès au public
  - ☐ request handled by collecting agency/demande traitée par l'organisme responsable de la collecte des données

Media of output/Moyen utilisé pour l'extraction des données (CMO):
- ☐ magnetic tape/bande magnétique
- ☐ diskette/disquette
- ☐ CD-ROM/disque optique
- ☐ listing/listes
- ☐ plots, graphs/tracés, graphiques
- ☐ published report(s)/rapport(s)
- ☐ microfiche
- ☐ maps/cartes
- ☐ other/autre
- . briefly describe other/brève description:

Non computer based systems/Systèmes non-informatisés (NCB)

Storage media/Moyen de classement (NCSM):
- ☐ remote sensing/télédétection
- ☐ maps/cartes
- ☐ unpublished hardcopy/document non publié
- ☐ published report(s)/rapport(s)
- ☐ microfiche
- ☐ other/autre
- . briefly describe other/brève description:

Dissemination of data/Diffusion des données (NCDD):
- . describe data access/description de l'accès aux données:

Media of output/Moyen utilisé pour l'extraction des données (NCMO):
- ☐ maps/cartes
- ☐ unpublished hardcopy/document non publié
- ☐ published report(s)/rapport(s)
- ☐ microfiche
- ☐ other/autre
- . briefly describe other/brève description:

Fees for dissemination?/Frais de diffusion? (FEE) no/non ☐ yes/oui ☐ specify/précisez:

Agency reference number to identify collected data/Numéro de référence de l'agence pour identifier les données recueillies (example/exemple: field sheets notes, cruise number, .../carnet de notes, numéro de la croisière, ...) (ARN)

Designated contact/Personne-contact désignée:	
Name/Nom (CN1):	Name/Nom (CN2):
Title/Titre (TI1):	Title/Titre (TI2):
Affiliation (AF1):	Affiliation (AF2):
Business address/adresse (AD1):	Business address/adresse (AD2):
Telephone no./No de téléphone (TEL1):	Telephone no./No de téléphone (TEL2):

Funding agency(ies)/Organisme(s) parrain(s) (FUND):

Publications generated from the collection/Publications relatives à la collection de données (PUB):

References or titles of publications consulted in collecting or useful in analysing the data/Références ou titres des publications consultées pendant la collecte (REF):

Keywords/Mots-clés (KEY):

Check off one or more to describe general headings for the collection/Cocher un ou plusieurs items pour décrire les thèmes généraux de la collection (CLA):

(01) ___ Physiographic data/Données physiographiques
(02) ___ Streamflow and water level/Débit et niveau de l'eau
(03) ___ Groundwater/Eaux souterraines
(04) ___ Glaciology/Glaciologie
(05) ___ Water quality/Qualité de l'eau
(06) ___ Sediment/Sédiment
(07) ___ Water use/Utilisation de l'eau
(08) ___ Planning and management/Planification et gestion
(09) ___ Other/Autre:

Narrative description of data collection/Description de la collection de données (DES):